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UNIVERSITY OF ALBERTA

Allowable Cut Effects of Various Intensive Management and Land Base Options in the Boreal Mixedwood

by

LAURIE ANN ONISHENKO

(C)

A thesis

submitted to the Faculty of Graduate Studies and Research

in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE

Department of FOREST SCIENCE

EDMONTON, ALBERTA

Fall 1991

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Allowable Cut Effects of Various Intensive Management and Land Base Options in the Boreal Mixedwood

submitted by **Laurie Ann Onishenko** in partial fulfillment of the requirements for the degree of **Master of Science in Forest Science.**

Dr. James A. Beck, Jr. Supervisor

Dr. Jack D. Heidt

Dr. William E. Phillips

Date: October 7, 1991

Dedication

To my Grandma, Yvonne Boulanger-Bellavance, for her conviction that I would finish ...

To my friend, Bernie LeBlanc, for his final push that motivated me into finishing ...

To my husband, Percy Sekora, for his patience and support while I finished my thesis.

Abstract

This study is concerned with the manner in which white spruce/trembling aspen mixedwood stands within the Boreal Forest Region (Rowe, 1972) should be managed and utilized. Impacts on allowable cut of both softwood and hardwood are evaluated using a harvest scheduling model. The study first observes harvest volumes produced from the coniferous and deciduous land bases, as currently defined by the Alberta Government.

On the conifer land base, increases in conifer allowable cut are sought through application of two forest management practices, softwood understorey release and/or species conversion. Several conclusions are drawn from this case study that would be applicable to other forests with similar age class structures and species distribution. When managing the coniferous land base, it is concluded that conversion of mixedwood stands to pure conifer can increase the conifer fibre production over the planning horizon by approximately 6%; the long run sustained yield average also increases,by 13.2%. If the mixedwood stands are allowed to revert to deciduous, the conifer harvest over the planning horizon decreases by 16.2% and the long run sustained yield falls by 36.5%. A 7% increase in conifer allowable cut can be achieved through releasing the softwood component within the mixedwood stands. When both management practices occur, release of mixedwood and conversion

to conifer, the resulting conifer volume production over the planning horizon grows by 13.6%.

The study concludes that if both release of mixedwood and choice in species regeneration are allowed, then the use of the deciduous fibre within the conifer land base can occur without significantly impacting conifer volume production.

Finally, the study amalgamates the two land bases into an integrated land base. Managing the integrated land base for both conifer and deciduous products yields superior allowable cuts. It can be managed to increase production of the most desirable product, softwood or deciduous; management for either product yields greater total fibre as compared to management of separate land bases. The study thus recommends that the current policy used by the Government of Alberta to define land bases be reviewed.

Acknowledgement

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Finally, I thank the Timber Management Branch of Alberta Forestry, Lands, and Wildlife for providing the Slave Lake forest inventory data on which this thesis is based.

Table of Contents

CHAPTER		Page
1.0	INTRODUCTION	1
1.1	Objectives of Study	4
1.2	Literature Review	7
2.0	METHODS	12
2.1	General Characteristics of the Slave Lake Forest	12
2.2	Characteristics of Study Area	13
2.3	Computer Model Description	14
2.4	The General Design of the Model Input File	15
2.5	Yield Tables	16
3.0	BASERUNS	19
4.0	CONIFEROUS LAND BASE: Options for Increases in AAC	25
4.1	Effects of Different Regeneration Practices	25
4.2	Effects of Intensive Forest Management	29
4.3	Joint Production of Softwood and Hardwood Fibre from Conifer Land Base	36
4.3.1	No Release of Mixedwood Stands	37
4.3.2	Allow Mixedwood Stands to be Released	42
5.0	INTEGRATED LAND BASE	48
5.1	Percent of Deciduous in Total Volume over the PH	52
5.2	Percent of Coniferous in Total Volume over the PH	53

5.3 Highest Deciduous Volumes 54

5.4 Highest Coniferous Volumes 56

5.5 Highest Total Volumes 56

5.6 Runs Superior to #2+#16 57

5.7 General Observations 58

6.0 CONCLUSIONS AND RECOMMENDATIONS 59

6.1 Conclusions 59

6.2 Recommendations 62

7.0 LITERATURE CITED 64

APPENDIX : Yield Tables 69

List of Tables

		Page
Table 1:	SUMMARY of Baseruns	24
Table 2:	SUMMARY of Section 4.1 Runs	27
Table 3:	SUMMARY of Section 4.2 Runs	33
Table 4:	SUMMARY of Section 4.3.1 Runs	39
Table 5:	SUMMARY of Section 4.3.2 Runs	46
Table 6:	SUMMARY of Chapter 5 Runs	51

List of Symbols and Abbreviations

Symbols:

m^3	=	cubic meters
M	=	thousand
ha	=	hectare
km^2	=	square kilometers

Abbreviations:

AAC	=	Annual Allowable Cut
CLB	=	Coniferous Land Base
DLB	=	Deciduous Land Base
CP	=	Conversion Period
CPA	=	Conversion Period Average
PCP	=	Post Conversion Period
LP	=	Linear Program
LRSYA	=	Long Run Sustained Yield Average
MW	=	Mixedwood
PH	=	Planning Horizon

1.0 INTRODUCTION

The Boreal Forest Region (Rowe, 1972) of Canada extends from Newfoundland and the Labrador coast west to the Rocky Mountains, then north into the Yukon. Within this Forest Region lies the Mixedwood Section (B.18a) (Rowe, 1972). As the name implies, a mixture of tree species, both hardwoods and softwoods, grow in this area. The predominant conifer species is Picea glauca (Moench) Voss [white spruce]; the dominant hardwood species is Populus tremuloides Michx. [trembling aspen]. Throughout this report, the term mixedwood will refer to a white spruce/trembling aspen forest stand or covertype. Other tree species growing in Mixedwood forests include: Picea mariana (Mill.) B.S.P. [black spruce], Pinus banksiana Lamb. [jack pine], Pinus contorta Dougl. [lodgepole pine], Populus balsamifera L. [balsam poplar], Abies balsamea (L.) Mill. [balsam fir], Betula papyrifera Marsh. [white birch], and Larix laricina (Du Roi) K. Koch [tamarack].

Alberta has over 100,000 square miles of boreal mixedwood forest (McDougall, 1988). In the past, only the coniferous portion of mixedwood stands was normally harvested and any hardwood harvest came from pure hardwood stands. Hardwoods in Alberta represent 45% of the Allowable Cut, but less than 5% of the actual harvest (Brennan, 1988). Until recently, trembling aspen has been considered a "weed

species" as it competes with the conifers and impedes their growth. Recent technological advances have added new products to the market; these include kraft hardwood pulp, chemi-thermal-mechanical pulp and oriented strand board. Hardwood is no longer a "weed" but is a commercial tree species.

A tremendous amount of knowledge and information exists on the ecology, physiology, and management of individual tree species. However, research is lacking on methods by which these species can be managed on an integrated basis. The Mixedwood Forest Section is a very diverse and productive area. It is usually nutrient- and moisture-rich, and supports a wide variety of flora and fauna. These attributes lead to increased management flexibility, but also make management more complex. Long-term wood supply, utilization standards, silviculture opportunities, rotation ages, mean annual increment, soil types, wildlife, diversity of species, et cetera are all considerations when determining management regimes for forests, especially for the Mixedwood forest.

In Alberta, timber allocation and harvest is typically determined by dividing the land into coniferous and deciduous land bases. Traditionally, emphasis has been placed on conifer fibre, hence the conifer land base criterion was developed. The conifer land base includes any forested stands containing 50+ m^3/ha of conifer fibre or capable of producing that amount by the age of 120 years. The deciduous

land base includes those areas which do not meet the above conifer standard but meet a similar standard by measuring deciduous fibre. The boreal mixedwood stands usually fall into the coniferous land base and historically have only been managed for conifer production. Since many of these stands contain a significant amount of deciduous volume, the question arises as to whether an integrated management approach, one that considers both conifer and deciduous production, is needed.

1.1 Objectives of Study

Given the increasing importance of trembling aspen as a commercial tree species, the vast quantities of Boreal Mixedwood Forest in Alberta, the current and future deciduous harvesting needs and existing research on the relationship and response of white spruce and aspen in mixedwood stands, the objectives of this thesis are as follows.

Objective #1

Evaluate the effects on Annual Allowable Cut (AAC) and Long Run Sustained Yield Average (LRSYA) of various regeneration scenarios applied to coniferous, deciduous and mixedwood stands. The current regeneration policy in Alberta is to "reforest according to what was growing on the site prior to harvest." In regards to mixedwood stands if the mixedwood stand is merchantable according to the coniferous land base criterion, it shall be reforested to conifer. This policy however, may not meet the needs of forest management.

The AAC is the amount of fibre that can be harvested each year from the forest. A policy of non-declining yields is imposed as the harvest volume should be sustainable into the future. Non-declining yields infer that the amount of fibre harvested in any year must be greater than or equal to the harvest of the previous year. The LRSYA is the amount of fibre the second generation forests, under an assumed management level, can grow each year.

Forest-level management regimes for regeneration are used versus stand-level management because it is the effect on AAC, over the entire planning horizon (PH), and for the total forested land base, that is being observed.

Objective #2

Determine the effects on allowable cuts when various intensive management options, from prior research and literature, are applied to mixedwood stands. Impacts on fibre production are tracked through the use of a computer model which allows different management regimes to be applied to the mixedwood stands.

The primary factors observed when analyzing the fibre production are: the total conifer production over the PH, the total deciduous production over the PH, and the grand total (conifer + deciduous) over the PH.

Objective #3

Determine the effect on AAC of managing mixedwood stands for softwood production only as opposed to managing these stands for joint production of both conifer and hardwood.

Objective #4

Determine the effect on AAC of managing two separate land bases for either softwood or hardwood production versus managing one land base jointly for both products. That is, observe whether the allowable cut from an integrated land base is larger, smaller, or equal to the sum of the allowable cuts from coniferous and deciduous land bases.

The approach this thesis takes is to:

i) review the relevant literature and research that is applicable to the management of boreal mixedwood stands for this study,

ii) choose a representative study area and develop appropriate yield tables,

iii) develop baseruns to determine the basic AAC and LRSYA for the coniferous and deciduous land bases,

iv) systematically address each study objective comparing and contrasting different management scenarios to the baseruns, and

v) summarize the conclusions and make recommendations on any further work.

1.2 Literature Review

Companies within the forest industry have traditionally been in business to manufacture either coniferous forest products or deciduous forest products, but not both. Forest managers have normally intervened in the growth of their forested land base to ensure the desired species would dominate the stand at the end of the rotation. This has led to many studies on alleviating competition between species (Froning, 1980; Malik and Vanden Born, 1986; Sutton, 1985; Yang, 1989).

Much research has been done to help understand the silvics and ecology of trembling aspen. DeByle and Winokur (1985) have compiled research and information on aspen ecology and management in the Western United States. A similar report has been compiled by Maini and Cayford (1986) on the growth and utilization of poplars in Canada.

I.E. Bella (1975, 1986) has conducted extensive research leading to an understanding of the growth of aspen stands. Kirby, et al. (1957) have studied the growth and yield of aspen in Saskatchewan, while Steneker (1976) has furthered that research by developing management prescriptions for aspen growing in the prairie provinces of Canada. In all of these reports trembling aspen is the desired crop species.

Many studies describe the relationship of decay in aspen. Paul & Etheridge (1958) have developed tables to compare gross and decay volumes of aspen at different age classes for

the Slave Lake Forest of Alberta. Their findings indicate faster growing aspen stands show a smaller percentage of decay at all age classes. Age-decay, site-decay and clone-decay relationships exist in aspen which make comparison research difficult. In general, decay percentages of gross volume increase with age and genetic origin of aspen is more important than site quality for managing decay (Hiratsuka and Loman, 1984). If decay is the limiting factor for utilization of the aspen fibre, aspen should be harvested at the pathological rotation age; that is, when decay rates begin to exceed growth rates (Hiratsuka and Loman, 1984) or at 40-50 years of age (Paul and Etheridge, 1958).

Equally extensive research has been done to gain an understanding of the silvics and ecology of white spruce (Rowe, 1955; Stiell, 1969; Swan, 1971). Eis and Inkster (1972) have published research on white spruce cone production. Owens and Blake (1985) have studied the reproductive processes of white spruce. Waldron (1961, 1966) has studied seedbeds needed for white spruce natural regeneration. Stiell (1976) has compiled a report on artificial regeneration of white spruce. Froning (1980) has investigated methods of logging hardwoods to reduce damage to white spruce understories.

Most research on the boreal mixedwood stands relates to converting and/or manipulating these stands to gain more softwood volume, usually at the expense of the hardwood.

Many people have been involved in studying growth of white spruce after release from competing vegetation (Frank, 1973; Sutton, 1969; Vincent, 1954) and in particular, after release from trembling aspen competition (Lees, 1966; Ontkean and Smithers, 1959; Pratt, 1966; Steneker, 1967).

Kagis (1952) has estimated at least one-third of the possible mature white spruce volume in mixedwood stands is lost due to aspen out-competing the white spruce, thereby suppressing the spruce growth. This has led to a great deal of research into releasing white spruce from overstorey competition and observing the resulting growth effects. Cayford's (1957) findings show that effects of aspen competition on white spruce growth begin when spruce trees are very young. He reports white spruce, suppressed by an aspen overstorey, are retarded in diameter, height, and volume growth for up to 100 years.

Lees (1966) has studied the release of white spruce from aspen canopies in the Slave Lake Forest of Alberta. His research demonstrates that ten years after release, the merchantable volume of white spruce will increase by 20-40%. His recommendation is to release the spruce prior to its growth into the aspen overstorey. Research by Frank (1973) shows complete release of white spruce trees, that is, cleaning out vegetation on all four sides of the tree, extends the growing season of the crop tree: circumference growth begins earlier in May and continues longer into

August. In a report by Arnup (1987), on the Moonbeam Plantation in Ontario, a white spruce plantation, established in 1951 and continuously hand-cleaned from competition, exhibited superior growth as compared to the control plantation. Tree ring increment measurement yielded 2.3 times more gross total volume/hectare on tended versus control plots; net merchantable volumes were 4 times greater, average diameter was approximately double, and average height was 50% greater. Baskerville (1961) has studied the resulting growth effect on white spruce when released from mountain maple. He has found height growth steadily increases for the 9 years of observation and, by the end of this time period, the height of the released trees can be double that of the control trees.

Research by Cayford (1957) and Lees (1966) demonstrates that white spruce in the 20- to 40-year-old age class appears to have the greatest growth response when released. Steneker (1974) has studied growth effects resulting from release of older white spruce trees growing in Saskatchewan. He could not see any noticeable increase in volume over a 10 year period and concludes white spruce over 70 years of age does not respond well to release.

Research into white spruce-trembling aspen mixedwood stands has been ongoing since the 1950's (Jarvis et al., 1966; Johnstone, 1977; Kabzems et al., 1986; Kirby, 1962).

While most of the above literature looks at trying to manage for softwood at the expense of hardwood, concerns on joint management of white spruce and trembling aspen are now surfacing. Proceedings from a symposium held in Edmonton, in 1988, on the Management and Utilization of Northern Mixedwoods include some of the first formal discussions on managing mixedwood stands for production of both white spruce and trembling aspen. Many forest management dilemmas pertaining to mixedwood stands are highlighted by Schneider, Brace and Bella, Day and Bell, Murphy, and others in the published proceedings (Samoil, 1988).

Through the objectives of this study, the effects and implications on allowable cut from manipulating both conifer and hardwood volumes in boreal mixedwood stands are studied. The aforementioned research relevant to this study has been considered and used.

2.0 METHODS

In order to evaluate the impacts of various regeneration and intensive management scenarios, a study area with a substantial amount of Boreal Mixedwood Forest is needed. The Slave Lake Forest of Alberta meets this criteria and thus, is selected.

This chapter is divided into five sections which describe: general characteristics of the Slave Lake Forest; characteristics of the study area; the computer model, Timber Resource Allocation Method (Navon, 1971); the general design of the model input file; and yield tables used in the input files.

2.1 General Characteristics of Slave Lake Forest

The predominant covertype of the Slave Lake Forest is Boreal Mixedwood. The Slave Lake Forest (Anon., 1985a) occupies 54.1 km^2 of land in north-central Alberta. Of this area, 29.1 km^2 is productive forest land. Pure coniferous timber stands account for 26.6% of the productive land base, mixedwood stands account for 22.0% and deciduous timber stands account for the remaining 51.4%.

2.2 Characteristics of the Study Area

The case study area is within the productive area of the Slave Lake Forest. Data for this study, obtained from the Timber Management Branch, Alberta Forestry Lands & Wildlife consists of four covergroups: pure coniferous, coniferous/deciduous (C/D), deciduous/coniferous (D/C) and pure deciduous. The C/D and D/C covergroups are classified as to whether or not they meet the conifer land base criterion. Those that do are placed into the "mixedwood" timber type and are considered part of the coniferous land base. Those that don't are placed in the deciduous land base. This is summarized below:

Timber Type	Site Type	Hectares	Timber Class Label
Conifer	Good	53,500	A
Conifer	Medium	578,759	B
Conifer	Fair	204,100	C
		836,358	
Mixedwood	Good	55,000	D
Mixedwood	Medium	553,769	E
Mixedwood	Fair	81,100	F
		689,869	
Deciduous	Good	187,789	G
Deciduous	Medium	1,312,369	H
Deciduous	Fair	116,910	I
		1,617,068	
Total Forested Land Base		3,143,295	

In this study, the coniferous land base encompasses those timber types with class labels A-F and totals 1.526 million hectares. The deciduous land base encompasses timber types with class labels G-I and an area of 1.617 million hectares.

The integrated land base encompasses all timber types for a total area of 3.143 million hectares.

2.3 Computer Model Description

A computer model, Timber Resource Allocation Method (Timber RAM) is the vehicle used to study the fibre production and utilization. The model, originally developed by Navon (1971) at the Pacific Southwest Forest and Range Experiment Station, has been modified by the University of Alberta to run on an IBM computer and provide metric output. This modified version of Timber RAM is chosen for the study since it is currently used by Alberta Forestry, Lands & Wildlife for determining allowable cuts on their management units.

Timber RAM is a Model I linear-programming-based harvest scheduling model that can be used in forest-level management planning (Johnson & Scheurman, 1977). For a complete description and understanding of the model and its requirements, see "Timber RAM and the University of Alberta" (Kristoff, et al., 1986).

2.4 The General Design of the Model Input File

The basic parameters used in setting up the input files for this study are:

- The planning horizon (PH) for all runs is 18 decades (180 years) since this is twice the average rotation age.
- A policy of non-declining flow is maintained throughout the PH by imposing appropriate harvest volume control constraints in both the Conversion Period (CP) and the Post Conversion Period (PCP).
- The CP, or length of time for which constraints are placed on harvest volumes to begin regulating the forest, is set at 6 decades for two reasons:

i) It is shorter than the shortest rotation, therefore preventing regenerated yields (of second cuts) from entering into the Conversion Period Average (CPA). Thus stands with shorter rotations will not unduly influence the average Annual Allowable Cut (AAC) for the CP.

ii) Results would still be applicable if management practices change and make it possible to shorten average rotation ages.

- The PCP consists of the remaining 12 decades to the end of the PH. Constraints are placed on the PCP Average allowable cut to achieve a non-declining flow policy through linkage to the CPA.

- Regenerated timber is established using genetically unimproved planting stock and will be clearcut when it reaches rotation age.
- The objective function of the linear program is "maximize harvest volume over the CP." The species being maximized will change with different runs.
- Through use of different yield tables, forest management practices, such as stand release and reforestation involving species conversion, are simulated.

2.5 Yield Tables

AFORISM (Alberta Forest Service Phase 3 Inventory) data provides information on: area distribution by site class, age class and covergroup and covergroup volumes by age class to a specified utilization standard. This data is used to construct nine basic yield tables for the existing forest: three species yield tables -- pure conifer, mixedwood, and pure deciduous; and for each of these species a yield table for one of three site classes -- good, medium, and fair. Standing timber yields of the existing forest are included in Appendix I, Tables 1-4.

The pure conifer yield tables are weighted averages of the percent composition of lodgepole pine and white spruce. The pure conifer raw data has negligible volumes of other cónifers such as black spruce, tamarack, and balsam fir. Since these species have growth rates more similar to white

spruce than lodgepole pine, they are included as part of the white spruce component.

In the mixedwood yield tables white spruce is kept separate from other conifers as the other conifers may respond differently to stand tending. A negligible amount of lodgepole pine volume is found in the raw data for mixedwood stands, therefore this species is included with the other conifers.

The yield tables developed are adjusted for actual average stocking (on an area-weighted basis) based on the Yield Tables for Unmanaged Stands in the Slave Lake forest. Any stocking greater than 100% is assumed to equal 100%. Growth response assumptions from the literature are applied to the yield tables of the existing forest to develop yield tables for intensive forest management options. Examples of these are included in Appendix I, Tables 5 and 6.

The regenerated timber yields are developed with four assumptions: (i) if no species conversion occurs, then the stand is reforested in the same proportions as what was present prior to harvest, (ii) regenerated stands have 100% stocking, (iii) a managed forest attains the same maximum mean annual increment as an unmanaged forest, but by the desired (administratively set) rotation age for the site/species combination and (iv) regeneration lags are included for appropriate site/species combinations.

The volume at rotation for regenerated timber is based on actual tree age. For example, if the administratively set rotation is 7 decades and the regen lag is 4 years, the trees are 66 years old at the second harvest. Appendix I, Table 7 details the regeneration volumes, lags, species, ages, et cetera. The standing timber volumes are combined with regenerated timber volumes to build the yield tables (summarized in Appendix I, Table 8).

3.0 BASERUNS

The nine timber classes of the Slave Lake Forest are classified, according the current land base criteria, into the conifer land base (CLB) and the deciduous land base (DLB). In this chapter two baseruns are developed which determine the Annual Allowable Cut achievable from the CLB and the DLB. These baseruns assume current forest management practices used by industry which comply with Alberta Government regulations. The baseruns are used as a starting point from which to compare all subsequent chapter runs.

Method

The CLB baserun includes timber classes A-F, and the DLB baserun includes timber classes G-I. The objective function is set up to maximize fibre production over the Conversion Period and incorporates a flow policy of non-declining yields. The average harvest volume over the CP, the total production over the PH and the LRSYA of each land base are observed.

Assumptions used in constructing the Baserun for the CLB

1. Only the coniferous portion of the mixedwood stands is included for the standing timber yields.
2. Coniferous rotation ages (in decades) are administratively set for the second forest:

Rotation Ages (Decades):

Site	Conifer	Mixedwood
Good	7	8
Medium	8	9
Fair	10	11

3. Second rotation (managed) forests attain the maximum mean annual increment of an unmanaged forest by the time the administratively set rotation age occurs.
4. Second growth conifer forests include a four-year regeneration lag (unless otherwise specified). This is based on comparing the provincial average top height of 20-year-old white spruce (AFS unpublished data) to that found in Phase 3 Yield Tables (Anon, 1985b); the data shows tree heights lag about 4 years behind the yield table prediction. This is also supported by Velpar herbicide trials at Calling Lake, Alberta.[1] The height of the control seedlings is equal to the provincial average; and the height of the treated (herbicided) seedlings is equal to Phase 3 yield tables. Suppression of competition through herbicide application would equate to a zero regeneration lag.

1 Personal data collection by Onishenko, 1987.

5. Pure conifer stands growing on good sites have an additional regeneration lag of 4 years (bringing lag to 8 years) due to heavy vegetative competition normally found in nutrient-rich sites. Actual tree age at rotation is 62 years.
6. Coniferous land base is regenerated to "what was there before."
7. Regenerated volumes are at 100% stocking.
8. Maximize coniferous volume over the CP.

Assumptions used in constructing the Baserun for the DLB

1. Net deciduous volumes are contained in the Standing Timber Yield Tables for deciduous as per the Alberta Phase 3 yield tables (Anon., 1985b).
2. For deciduous, after 70 years of age, only 75% of the volume is merchantable; after 100 years of age, no merchantable volume remains (Steneker, 1976; Thomas et al., 1960; Thomas, 1968). These percentages are based on lumber recovery attainable after the onset of decay. These recovery percentages should not be as severe when deciduous fibre is used for pulpwood.
3. Deciduous regeneration remains untended. Rotations and volumes at rotation (Steneker, 1976) used for second and subsequent deciduous forests are:

70 years	280 m^3/ha	- for good sites
70 years	228 m^3/ha	- for medium sites

These values are comparable to Phase 3 Yield Tables for Unmanaged Stands (Anon., 1985b) which yield 288 m^3/ha for 70 year-old hardwood growing on good site classes, and 208 m^3/ha for 70 year-old hardwood growing on medium site classes. If the method used to calculate volume at rotation for second generation forests of conifer and mixedwood (that is, using the maximum mean annual increment occurring at the desired rotation age) is used for hardwood yields, the yield table values would be 301 m^3/ha for good sites, and 213 m^3/ha for medium sites.

4. Deciduous regeneration on fair sites yields 58.6 m^3/ha at rotation age of 110 years.
5. No regeneration lag exists for pure deciduous stands.
6. Maximize deciduous volume production over the CP.

Results

The coniferous land base produces 33,730M m^3/decade over the entire PH and gives a LRSYA of 28,403M m^3/decade (run #1). The harvest volumes are greater than the LRSYA of second growth forests because of the age class structure in the forest. Since the forest is not regulated and there is an excess amount of growing stock, the harvest levels can exceed growth until regulation is achieved.

Management of the DLB (run #2) yields a LRSYA of 50,880M m^3/decade and the production over the CP averages 29,903M m^3/decade. The reason for the large discrepancy between the CPA and the LRSYA is that the virgin forest has 188M hectares (or 11.7%) of hardwood forest older than 100 years. The yield assumption used for hardwood forests is based on research conducted by Thomas, et al. (1960). It assumes deciduous stands do not contribute any volume after age 100. Timber classes older than this are therefore harvested with zero volume and must be regenerated and harvested a second time before they contribute to the allowable cut. As the CP is only 6 decades, and rotation ages are from 7 to 11 decades long, these stands do not add fibre until the PCP. The PCP Average of 48337M m^3/decade is much closer to the LRSYA, because most stands are now contributing to the allowable cut. The two baseruns are summarized in Table 1.

Table 1: SUMMARY OF BASERUNS

Run Number:	#1	#2
Timber Classes:	A - F	G - I
Land Base:	Conifer	Deciduous
Area (M hectares)	1526.3	1617.1
Objective Function:	Maximize Conifer over the CP	Maximize Deciduous over the CP
Assumptions & Periodic Constraints	Good, conifer sites have 8-yr regen lag All others have 4 yr lag	No regen lag
Regeneration of the		
Conifer to:	Conifer	-
Mixedwood to:	Mixedwood	-
Deciduous to:	-	Deciduous
Conifer CPA (M m3/decade)	33730	-
Conifer PCP Average (M m3/decade)	33730	-
Deciduous CPA (M m3/decade) (in decades x-y)	-	21328.2 (1-3): 33546.8 (4,5): 48337.5 (6)
Deciduous PCP Average (M m3/decade)	-	48337.4
Conifer over PH	607139	
Deciduous over PH		759463
GRAND TOTAL over PH (M m3/decade)	607139	759463
Conifer LRSYA (M m3/decade)	28403	-
Deciduous LRSYA (M m3/decade)	-	50880.1

4.0 CONIFEROUS LAND BASE: Options for Increases in AAC

This chapter evaluates the increases in AAC relative to Baserun #1, achievable from the conifer land base.

The chapter is divided into three sections, each addressing one study objective. Section 4.1 evaluates the effects on AAC and LRSYA of different regeneration options applied to the conifer and mixedwood stands. Section 4.2 determines the allowable cut effect from implementing intensive forest management practices. Section 4.3 evaluates the effects of managing mixedwood stands for softwood production only, versus joint production of softwood and hardwood.

4.1 Effects of Different Regeneration Practices

Introduction

Baserun #1 is conifer-biased as it assumes the replanting of mixedwood stands is done with conifer seedlings, as per current government and industry practice. In 1984, Juvenile Stand Surveys (JSS) were performed by the Alberta Forest Service. 318 satisfactorily regenerated cutblocks harvested between 1967-1974 were re-surveyed. The findings show that the species composition of the cutblocks had changed: 50% reverted to hardwood, 16% to mixedwood, and only 33% remained as conifer (Drew, 1988). Baserun #1 takes these results into account by using a conservative estimate for LRSYA in terms of conifer production, as mixedwood regenerates to mixedwood.

Method and Assumptions

In this section, Objective 1 is addressed. Runs are performed to analyze the effects on LRSYA had those same mixedwood stands remained as pure conifer stands after planting (run #3) or had they reverted to pure deciduous (run #4). For the stand conversion in run #3 to occur, some type of forest cleaning, manual or herbicide, must be performed. In addition to the reason noted above, Baserun #1 takes a conservative approach in estimating of LRSYA due to the assumption that pure conifer stands growing on good sites have an 8-year regeneration lag. Runs are performed to test the effects on LRSYA of reducing this regeneration lag to 4 years (runs #5 and #6).

Results

Results for these runs are given in Table 2 and summarized below:

Run #	Mixedwood stands regenerated to:	Regen Lag on Good Conifer sites (yr)	LRSYA M m^3/decade
1	Mixedwood	8	28,403
3	Conifer	8	32,158
4	Hardwood	8	18,031
5	Mixedwood	4	28,495
6	Conifer	4	32,339

Table 2: SUMMARY OF Chapter 4.1 RUNS #3 - #6

Run Number:	#3	#4	#5	#6
Timber Classes:	A - F	A - F	A - F	A - F
Area (M hectares)	1526.3	1526.3	1526.3	1526.3
Objective Function:	Maximize Conifer over the CP	Maximize Conifer over the CP	Maximize Conifer over the CP	Maximize Conifer over the CP
Assumptions & Periodic Constraints:	Good,conifer sites have 8-yr regen lag All others have 4 yr lag:	Good,conifer sites have 8-yr regen lag All others have 4 yr lag: Decid = 0 lag:	All sites have 4-year regen lag	All sites have 4-year regen lag
Regeneration of the Conifer to:	Conifer	Conifer	Conifer	Conifer
Mixedwood to:	Conifer	Deciduous	Mixedwood	Conifer
Deciduous to:	-	-	-	-
Conifer CPA (M m3/decade)	35735	29020	33786	36031
Conifer PCP Average (M m3/decade)	35735	29020	33786	36031
Conifer over PH (M m3/decade)	643228	522358	608144	648558
Conifer LRSYA (M m3/decade)	32158	18031	28495	32339

When mixedwood stands are regenerated/converted to pure conifer the LRSYA increases by 13.2% (run #3 versus run #1; run #6 versus run #5). The basic premise of forest management is harvest = growth, thus this increased longterm growth through stand conversion allows the harvest level over the CP to rise by 5.9%.

If the mixedwood stands are allowed to completely revert to hardwood, the conifer LRSYA decreases by 36.5%. This dramatic decrease has a negative impact on the average conifer harvest which drops by 16.2% over the CP.

Because only 7% of this land base is on good site classes, the effect of the additional 4 year regeneration lag applied to conifer growing on good sites is insignificant. The changes in both the LRSYA and the average harvest over the CP are less than 1% (run #5 versus #1; #6 versus #3).

4.2 Effects of Intensive Forest Management

Introduction

White spruce is a shade tolerant species (Hosie, 1979) and occupies a role as either a sub-climax or climax species of mixedwood boreal stands. Because of its physiology, it responds well to release. That is, when the overstorey is removed, this species quickly responds to the increased light, space, moisture and to the reduced competition, through extra volume growth. This section of the study addresses Objective 2. It evaluates the possibility of increasing conifer yields through silvicultural treatments which release the conifer component from the aspen canopy of mixedwood stands.

Method and Assumptions

All assumptions from Baserun #1 are in effect: land base; rotation ages; regeneration species; regeneration lags. Six runs are analyzed for increases in CPA and LRSYA based on these additional assumptions:

1. Mixedwood stands > 60 years are clearcut; only the coniferous portion of the volume is added to the AAC.
2. Mixedwood stands growing on good and medium site classes and ≤ 60 years are released by removing the deciduous overstorey. Release response:
   i) Sites of 50-60 years are released at age 60. Growth does not increase for five years

following release because the trees are in shock (Brace & Bella, 1988; Yang, 1989). Over the next 35 years, 260 m^3/ha of white spruce growth results on good sites and 189 m^3/ha on medium sites (Yang, 1989). As no research exists to show otherwise, the assumption is made that, after this 40-year period, white spruce (at age 100) grow as per Alberta Phase 3 yield tables (Anon, 1985).

ii) Sites of 0-40 years are released at age 40 and respond over the next 40 years as described above (Assumption 2i). This is contrary to the recommendations of Yang (1989). He suggests the release of white spruce be done at age 25-30 for maximum conifer growth and to prevent aspen sprouts and other underbrush competition. Kagis (1952) found that current annual increment of white spruce starts to drop around 30 years when the tops of the white spruce reach the crown of the aspen. However, because the study will later analyze maximizing both deciduous and coniferous fibre production and runs must be comparable, 40 years is selected as the age.

3. Other conifers (black spruce, tamarack, pine, and balsam fir) within the mixedwood stands could respond, when released, in one of three ways:

   i) Other conifers grow as per yield table; that is, only the white spruce responds to the release.

   ii) The response from other conifers: they have 1.25 times more volume 40 years after release; after this period mixedwood stands grow as per Alberta Phase 3 yield tables (Anon, 1985b).

   iii) Other conifers respond by having 1.5 times more volume 40 years after release; after this period stands grow as per the Alberta Phase 3 yield tables (Anon, 1985b).

   The study by Brace & Bella (1988) on growth and yield of white spruce after release forecasts 550-590 m^3/ha at 100 years of age on good sites. A comparison of these figures to the Yield Table values in this study, shows this study uses conservative estimates (only 358 m^3/ha of white spruce on good sites). The lower yields could be due in part to the assumption that the release response only lasts 35 years.

4. Two runs are done for each section (i-iii) of Assumption #3 to incorporate regeneration options (as in Section 4.1).

   i) In the first run, mixedwood stands regenerate to pure conifer stands (via species conversion).

ii) The second run has mixedwood stands regenerating to mixedwood. The release treatment is applied to all second growth mixedwood forests at age 40.

Results

By releasing the mixedwood stands under 60 years of age, and having the stands regenerating to mixedwood for subsequent release treatments, the volume harvested each decade through the CP and PCP is increased by 6.9% (Table 3 run #8 versus #1). This type of silvicultural treatment (run #8) on mixedwood stands produces a 1% greater increase in AAC over the PH as compared to converting mixedwood stands to pure conifer plantations (run #3 gives a 5.9% increase). However, the release treatments do not increase the LRSYA because they do not change the species or volumes in regenerating forests. The increased volume over the PH arises solely from the release treatments. At this point, forest managers should weigh the costs of releasing mixedwood stands versus converting mixedwood stands to pure conifer plantations to determine which method is preferable for the increased volume benefit.

Species conversion of the mixedwood stands to pure conifer again increases LRSYA by 13.2% (run #7 versus #8; #9 versus #10; #11 versus #12). Performing both silvicultural treatments: release of the mixedwood stands and converting them to conifer increases the conifer harvest level over the PH by 13.6% (#7 versus #1) and the LRSYA by 13.2%.

TABLE 3: SUMMARY OF Chapter 4.2 RUNS #7 - #12

Run Number:	#7	#9	#11
Timber Classes:	A - F	A - F	A - F
Area (M hectares)	1526.3	1526.3	1526.3
Objective Function:	Maximize Conifer over the CP	Maximize Conifer over the CP	Maximize Conifer over the CP
Assumptions & Periodic Constraints:	As per Baserun #1	As per Baserun #1	As per Baserun #1
Regeneration of the			
Conifer to:	Conifer	Conifer	Conifer
Mixedwood to:	Conifer	Conifer	Conifer
Deciduous to:	-	-	-
Release MW stands < 60 yrs response of "other conifers"	YES - forced none	YES - forced 1.25X volume	YES - forced 1.5X volume
Conifer CPA (M m3/decade)	38304	38368	38432
Conifer PCP Average (M m3/decade)	38304	38368	38432
Conifer over PH	689464	690619	691775
GRAND TOTAL over PH (M m3/decade)	689464	690619	691775
Conifer LRSYA (M m3/decade)	32158	32158	32158

TABLE 3: SUMMARY OF Chapter 4.2 RUNS #7 - #12
page 2

Run Number:	#8	#10	#12
Timber Classes:	A - F	A - F	A - F
Area (M hectares)	1526.3	1526.3	1526.3
Objective Function:	Maximize Conifer over the CP	Maximize Conifer over the CP	Maximize Conifer over the CP
Assumptions & Periodic Constraints:	As per Baserun #1	As per Baserun #1	As per Baserun #1
Regeneration of the			
Conifer to:	Conifer	Conifer	Conifer
Mixedwood to:	Mixedwood	Mixedwood	Mixedwood
Deciduous to:	-	-	-
Release MW stands < 60 yrs -response of "other conifers"	YES - forced none	YES - forced 1.25X volume	YES - forced 1.5X volume
Conifer CPA (M m3/decade)	36058	36120	36182
Conifer PCP Average (M m3/decade)	36058	36120	36182
Conifer over PH	649039	650156	651271
Deciduous over PH			
GRAND TOTAL over PH (M m3/decade)	649039	650156	651271
Conifer LRSYA (M m3/decade)	28403	28403	28403

Because the softwood component of the mixedwood stands in this forest is largely white spruce, the release response of other conifers has a negligible impact on CPA. If they respond as do the white spruce, at 1.5 times the volume, the harvest over the CP increases by 0.3%, and over the PH by 0.2% (#11 versus #7; #12 versus #8).

4.3 Joint Production of Softwood and Hardwood fibre from Conifer Land Base

This section evaluates the potential of maximizing the harvest of conifer fibre, as the primary product, and using the deciduous component of the mixedwood stands as a secondary product (Objective 3). This type of forest management enhances total fibre utilization of the resource. Minimum flows are required of the secondary product for feasibility in supporting a processing facility.

Method

A preliminary run, performed on the mixedwood timber, shows the mixedwood can sustain a deciduous harvest level of 1479M m^3/decade for the first five decades, and over 5000M m^3/decade thereafter. These values provide input for setting the minimum required levels of deciduous harvest.

Two sub-sections are included based on different intensive forest management assumptions. Release of the mixedwood stands is not allowed in the first sub-section but is allowed in the second. In both sub-sections, various regeneration scenarios are allowed.

4.3.1 No Release of Mixedwood Stands

Assumptions

1. Maximize conifer volume production over the CP subject to a minimum level of 1400M m3/decade of deciduous over the CP.
2. All those pertaining to conifer and mixedwood stands as per Baserun #1.
3. For deciduous stands, assumptions 1-5 as per Baserun #2, apply.
4. Both the conifer and deciduous yields of MW stands are included in the standing and regenerated yield tables.
5. Run #13: mixedwood is regenerated to mixedwood.
6. Run #14: The Timber RAM input file is set up to allow the linear program to select the species with which to regenerate the mixedwood stands. Each mixedwood stand has three management alternatives associated with it:

   C = pure conifer regeneration
   M = mixedwood regeneration
   A = pure deciduous regeneration (untended)

   Because choice in regeneration is allowed, the minimum level of deciduous is raised to 1600M m^3/decade in decades 3-6.

Results

The impact of having to maintain a minimum deciduous level through the CP is to decrease the conifer harvest over the PH by 1.3% (Table 4, run #13 versus run #1). Constraints on deciduous volumes harvested through the CP are met exactly. The level of deciduous harvest during the PCP increases dramatically as aspen from the regenerated mixedwood forests contributes to volume. The total volume (conifer + deciduous) over the PH in run #13 is 13.0% greater than in run #1. This would suggest more efficient utilization of the resource.

Run #14, in which the minimum deciduous harvest is raised to 1600M m^3/decade for periods 3-6, yields a conifer CPA of 35,701M m^3/decade, and the total conifer harvest over the PH is 642,618M m^3 (both are superior to run #1). The deciduous cuts are met according to specifications, but by the end of the conversion period, the deciduous resource is virtually depleted. The only deciduous contributing any volume in the PCP is that from mixedwood stands growing on fair sites since regeneration of these sites is controlled. Total deciduous volume over the planning horizon is 14,004M m^3. Total production (conifer + deciduous) is 656,622M m^3 over the PH. This is 8.2% greater than run #1. Increase in conifer volume accounts for 5.8% of this figure, the remainder is due to using the deciduous component when clearcutting the mixedwood stands.

TABLE 4: SUMMARY OF Chapter 4.3.1 RUNS #13 & #14

Run Number:	#13	#14
Timber Classes:	A - F	A - F
Area (M hectares)	1526.3	1526.3
Objective Function:	Maximize Conifer over the CP	Maximize Conifer over the CP
Assumptions & Periodic Constraints:	Min.deciduous: 1400/decade over the CP	Min. decid. 1400 (decades 1,2): 1600 (decades 3-6):
Regeneration of the		
Conifer to:	Conifer	Conifer
Mixedwood to:	Mixedwood	LP Chooses
Deciduous to:	-	-
Release MW stands < 60 yrs	No	No
-response of "other conifers"		
Conifer CPA (M m3/decade)	33283	35701
Conifer PCP Average (M m3/decade)	33283	35701
Deciduous CPA (M m3/decade)	1400	1400 (1) 1409 (2) 1600 (3-6)
Deciduous PCP Average (M m3/decade)	6523	462 (7) 0 (8-11,13) avg 866 (14-18)
Conifer over PH	599093	642618
Deciduous over PH	86672	14004
GRAND TOTAL over PH (M m3/decade)	685765	656622
Conifer LRSYA (M m3/decade)	28403	32158
Deciduous LRSYA (M m3/decade)	**	**

** = LRSYA for deciduous not calculated by LP

In run #14, the LRSYA of conifer fibre is 32,158M m^3/decade. Thus, it appears that when given the choice of regeneration options, the linear program reforested all mixedwood stands to pure conifer. This is a model effect arising from the objective function of maximizing conifer. Because of higher volumes at rotation and shorter rotations of pure conifer versus mixedwood regeneration, this increases the LRSYA, which in turn, allows the CPA to rise. Likely not all stands would be converted to conifer if the objective function was to maximize total fibre because the mean annual increments of second growth mixedwood and deciduous forests are greater than those of pure conifer. This will be studied in Chapter 5.

If the objective is to maximize total fibre production from the conifer land base, it is beneficial to force the regeneration of all MW sites back to mixedwood. The conifer harvest/decade is 7.3% lower throughout the PH in run #13 as compared to run #14. However, this is offset by the increased deciduous fibre utilization. Run #13 yields 4.4% more total fibre (conifer + deciduous) than does run #14. Run #14 shows higher conifer production than run #13; however, #13 would better sustain a deciduous processing facility.

If the objective is to maximize conifer fibre, neither run #13 nor #14 should be selected; run #11 (Section 4.2) provides an additional 7.6% more conifer volume than #14.

This lost conifer volume in #14 is not recovered through deciduous volume production over the PH. Total (conifer + deciduous) production of run #14 is 5.4% lower than run #11. In this case, use of the deciduous component of mixedwood stands impedes both conifer and total volume production.

4.3.2 Allow Mixedwood Stands to be Released

Introduction

In section 4.3.1, reforestation to hardwood was the only practice available to obtain greater hardwood production. In this section, two options are available to increase deciduous allowable cuts: regeneration to hardwood and utilization of the hardwood component of mixedwood stands as they are released. Because two methods are available to obtain deciduous volume, the minimum level of deciduous is raised to 1700M m^3/decade and this constraint is lengthened from 6 decades to 10. This set of runs builds on Section 4.3.1. The linear program is allowed to choose whether or not mixedwood stands are released and which species is used in regeneration.

Method and Assumptions

1. All those pertaining to conifer and mixedwood stands as per run #10. Run #10 shows some response by other conifers (1.25X volume), and reforests mixedwood to mixedwood.
2. For deciduous stands, assumptions 1-5 as per Baserun #2, apply.
3. The linear program chooses the species for regeneration of mixedwood stands (as per run #14).
4. Both conifer and deciduous yields of MW stands are included in standing and regenerated yield tables.

5. The linear program is given the choice of releasing MW stands ≤ 60 years, whether or not herbicide is used after release and which species is used in regenerating the stand. Each MW stand is provided with eight alternatives via assigning different yield tables (as per Appendix I, Table 8). These alternatives are:

- clearcut, no release; conifer regen
- clearcut, no release; mixedwood regen
- clearcut, no release; hardwood regen
- release + herbicide; conifer regen
- release + herbicide; mw regen
- release, no herbicide; conifer regen
- release, no herbicide; mw regen
- release, no herbicide; hardwood regen

i) Release + herbicide treatment: Hardwood is taken out in the first pass. A herbicide treatment is applied to the stumps to prevent suckering and re-establishment of aspen. Some hardwood may still regenerate, but the amount will not be significant and therefore, is not calculated in future yields. A constraint of minimum 40 years before re-harvest is imposed.

ii) When herbicide treatment is applied, the response of MW stands to the release is white spruce increases volume by 1.5X over the following 40 years and the "other conifers" responds at 1.25X their volume after this same time period (as in runs #9 and #10).

iii) Release, no herbicide treatment: Hardwood is taken out in the first pass and the same constraint of 40 years prior to the second harvest is imposed. Because herbicide treatments are not applied, aspen suckering will occur and is included in future yields.

When no herbicide treatment is used following release of the mixedwood stands, white spruce responds to release @ 1.5X volume, "other conifers" do not respond. Instead, the hardwood grows back at 15% stocking as per Alberta Phase 3 yield tables (Anon, 1985b). During the second pass, both the conifer and deciduous fibre are harvested.

Although release at age 25-30 years yields the greatest volume response in white spruce residuals, release cuttings in 40- to 50-year-old stands are more economically feasible due to the value of aspen. In spruce/aspen mixedwood stands, the aspen component is normally 10-15 years older than the spruce (Kabzems, 1971). By the time spruce reaches 40-50 years, the aspen component (50-65 years old) is harvestable and revenues from aspen harvest might defray release costs (Yang, 1989).

6. Run #15: Maximize conifer volume production over the CP subject to a minimum level of 1700M m3/decade of deciduous for the first 10 decades.

7. Run #16: Maximize conifer volume production over the CP subject to a minimum level of 1700M m3/decade of deciduous for the first 10 decades, and 1900M m^3/decade for the remainder of the PH.

Results

When the minimum deciduous constraint is raised to 1800M m^3/decade over the PH, the problem becomes infeasible. The deciduous production achievable during the first 10 decades is the limiting factor. Because of the decay assumptions, the deciduous component of the mixedwood stands has zero volume after age 100. Thus, harvesting of mixedwood stands older than 10 decades (especially during the first harvest) will not contribute to the deciduous volume.

When maximizing conifer yields, many mixedwood stands are released; these are mainly reforested to mixedwood or conifer. Very few stands use the management alternative of regenerating a MW stand to deciduous.

Constraining the deciduous cut for only 10 decades (Table 5, run #15) rather than the entire planning horizon (#16) does not significantly increase the conifer (only +0.4%). It does, however, significantly decrease the deciduous harvest (34% over the PH). As well, total production over the PH (both the softwood and hardwood harvest) decreases by 1.2% when deciduous is constrained for 10 decades only.

TABLE 5: SUMMARY OF Chapter 4.3.2 RUNS #15 & #16

Run Number:	#15	#16
Timber Classes:	A - F	A - F
Area (M hectares)	1526.3	1526.3
Objective Function:	Maximize Conifer over the CP	Maximize Conifer over the CP
Assumptions & Periodic Constraints:	Min.deciduous 1700/decade decades 1-10	Min.deciduous 1700/decade decades 1-10 1900/decade decades 11-18
Regeneration of the Conifer to:	LP Chooses	LP Chooses
Mixedwood to:	LP Chooses	LP Chooses
Deciduous to:	-	-
Release MW stands < 60 yrs -response of "other conifers"	LP Chooses -- as per mgmt alternative selected by the LP	LP Chooses
Conifer CPA (M m3/decade)	37323	37161
Conifer PCP Average (M m3/decade)	37323	37161
Deciduous CPA (M m3/decade)	1700 (1) 2112 (2) 1700 (3-10)	1700 (1) 2112 (2) 1700 (3-10)
Deciduous PCP Average (M m3/decade)	0 (11-14) 1700 (15) 0 (16) 3400 (17) 0 (18)	1900 (11-16) 3400 (17) 1900 (18)
Conifer over PH	671812	668890
Deciduous over PH	22513	34113
GRAND TOTAL over PH (M m3/decade)	694325	703003

** LP did not calculate Conifer or Deciduous LRSYA

Utilization of the deciduous component of mixedwood stands during release of the conifer allows the deciduous volume production during the first six decades to increase by 15.2% (#16 versus #14). As well, the conifer cut is raised by 4.1%.

Results of section 4.3.1 conclude that having to maintain a minimum flow of deciduous from the mixedwood stands via choice in regeneration species does not yield greater total volume over the PH. More volume was obtained through section 4.2, run #11 in which no minimum levels of deciduous harvest were required. The conclusion of this section is utilization of deciduous fibre, when releasing mixedwood stands together with choice in species regeneration, can increase total volume production over the PH. Run #16 shows an increase of 1.6% in total volume (conifer + deciduous) over the PH as compared to run #11.

However, if maximizing total conifer production over the PH is the goal, run #11 is still superior to #16 by 3.3%. Similarly, if maximizing total deciduous production over the PH is a measure, higher yields can be obtained through the runs in Section 4.3.1. The runs in this Section 4.3.2 are superior only when the goal is to maximize total volume production. This is the prelude to determining AAC from an integrated land base.

5.0 INTEGRATED LAND BASE

To test Objective 4, whether separate treatment of the land bases has sub-optimized total fibre production, the coniferous and deciduous land bases are amalgamated to form an integrated land base. The total fibre harvested on a non-declining flow basis from this integrated land base is then analyzed. Mixedwood stands are generally thought to be the most productive and efficiently used sites, in terms of highest yield/hectare.

In this chapter, all stands (conifer, mixedwood, and deciduous) have the option of regenerating to mixedwood yields through the set-up of the Timber RAM input files (reference Appendix I, Table 8). Since the objective function is to maximize total volume, the percentage of land being regenerated to mixedwood is observed. Even though mixedwood sites are more productive relative to pure conifer and pure deciduous, not all timber will convert to this type of stand. It is expected that a certain amount of pure deciduous and pure conifer plantations will be retained in the land base as mixedwood stands would not occur in the ratios needed to meet flow constraints placed on both products.

Method

The total volume of the stand, both the conifer and deciduous components, is placed in the yield table. The coniferous and deciduous harvest levels are traced through the use of the economic tables. Constraints are then placed on the components within the economic tables to ensure non-declining yields.

The constraints for the conifer and deciduous volumes come from output of the previous runs, considered to be the most desirable. The constraints for the deciduous volume are based on the cut/decade of baserun #2 and the deciduous cut/decade of run #16. The coniferous volume constraint is based on conifer produced in run #16. The linear program selects the optimum management alternatives with regard to release treatment and regeneration species.

Assumptions

1. Assumptions for rotation ages, release responses, regeneration lags, decay losses, et cetera are maintained from previous chapters.
2. Pure deciduous stands growing on fair sites are converted to conifer plantations as per recommendations by Steneker (1976). The yields from these plantations resemble those of mixedwood stands growing on fair sites. This assumption is based on Juvenile Stand Survey results which show that 10-15

years after harvest, there is a substantial presence of both white spruce and deciduous in the managed forests of Alberta (Drew, 1988).

3. The non-declining flow policy over the PH is applied to the total volume.

4. Minimum flows of conifer and deciduous volume are only required for ten decades. This would be critical to meet the needs of processing facilities on an annual basis and according to current government regulations, management plans must be updated every 20 years. Different techniques should, therefore, be available to grow, harvest, and process the forests over time.

Results

Four runs are performed on the Integrated Land Base. In each, the flow constraint on either the coniferous or deciduous production is increased (or removed) to gauge how this would affect the annual allowable cut.

The results of these runs are summarized in Table 6. Comparisons are made to the summation of results from Baserun #2 (deciduous land base) and run #16 (conifer land base) [#2+#16]. The data is analyzed in seven different sections:

i) percent of deciduous in total volume over the PH
ii) percent of coniferous in total volume over the PH
iii) highest deciduous volumes
iv) highest conifer volumes
v) highest total volumes
vi) runs superior to #2+#16
vii) general observations.

TABLE 6: SUMMARY OF Chapter 5 RUNS #17 - #20

Run Number:	#2+#16	#17	#18	#19	#20
Timber Classes:	A-I	A-I	A-I	A-I	A-I
Area (M hectares)	3143.3	3143.3	3143.3	3143.3	3143.3
Objective Function:	As per Previous Tables	Maximize Total Volume over the CP	Maximize Total Volume over the CP	Maximize Total Volume over the CP	Maximize Total Volume over the CP
Assumptions & Periodic Constraints: [volume/decade and decades]	As per Previous Tables	Min. conifer 37M/decade (decades 1-10) Min Hdwood 23M/dec. (1,2) 24.5M/dec (3-6) 53M/dec (7-10)	Min. conifer 38M/decade (decades 1-10) Min Hdwood 23M/dec. (1,2) 24.5M/dec (3-6) 53M/dec (7-10)	NO Minimum Conifer Min Hdwood 23M/dec. (1,2) 24.5M/dec (3-6) 53M/dec (7-10)	Min. conifer 38M/decade (decades 1-10) NO Minimum Deciduous
Regeneration of the					
Conifer to:	LP Chooses	LP Chooses	LP Chooses	LP Chooses	LP Chooses
Mixedwood to:	LP Chooses	LP Chooses	LP Chooses	LP Chooses	LP Chooses
Deciduous to:	Deciduous	LP Chooses	LP Chooses	LP Chooses	LP Chooses
Release MW stands < 60 yrs - response of "other conifers"	LP Chooses --- as per management alternative selected by the Linear Program				
Conifer CPA (M m3/decade)	37161	42961	42482	50335	42444
Conifer PCP Average (M m3/decade)	37161	40976	44181	26505	38454
Deciduous CPA (M m3/decade)	31602	24146	24161	24000	31578
Deciduous PCP Average (M m3/decade)	48337	54239	44338	67993	55052
Total CPA (M m3/decade)	68763	67107	66643	74335	74022
Total PCP Avg (M m3/decade)	85498	95215	88519	94498	93506
Conifer over PH	668890	749471	785069	620063	716115
Deciduous over PH	793576	795740	677021	959918	850091
GRAND TOTAL over PH (M m3/decade)	1462466	1545211	1462090	1579981	1566206

LP did not calculate Conifer or Deciduous LRSYA

5.1 Percent of Deciduous in Total Volume over the PH

In adding the two land bases together (#2+#16), deciduous production accounted for 54% of the total production over the PH. Of all the runs performed on the integrated land base, only run #19 yields a higher percentage of deciduous to total production (61%).

Run #20 yields the same percentage of deciduous to total volume as does the amalgamation of separate land bases. However, run #20 has 7.1% greater conifer, 7.1% greater deciduous, and 7.1% greater total volume production over the PH than does the separate land bases. This demonstrates the superiority of an integrated land base.

These integrated runs (#19, #20) have a higher CP and PCP average when both deciduous and coniferous production are added together, as compared to #2+#16. As well, in both, the total volume production (conifer + deciduous) over the PH is superior.

A more in-depth look at run #19 reveals that 61.7% of the land base regenerates to mixedwood stands, 37.6% regenerates to deciduous and only 0.7% regenerates to pure conifer. Two conclusions are drawn from this run:

i) mixedwood sites are the most productive even though their rotations are longer than both deciduous and pure conifer;

ii) over the PH, the shorter rotations of deciduous stands contribute 11.6% more fibre than the higher volumes at maturity of mixedwood stands.

5.2 Percent of Coniferous in Total Volume over the PH

In the remaining integrated runs, the percentage of conifer to total volume over the PH increases relative to runs #2+#16. In runs #17 and #18 the conifer is increased at the expense of deciduous production during the CP.

In #18, the total volume produced over the PH is virtually the same (-.03%) as compared to managing the land bases separately. However, run #18 produces 14.7% more conifer and 14.7% less deciduous over the PH. This run should not be discounted just because it does not produce a volume superior to the separate land bases. In fact, it may be desirable to manage the forest this way if conifer is more valuable than deciduous. Greater conifer volume over the PH is achieved through this management scenario than through any of the previous runs.

Run #17 clearly demonstrates the effectiveness of managing an integrated land base for optimum resource use. Deciduous production is not impacted (+0.3%), while conifer volume increases by 12%, and total volume over the PH yields an additional 5.7%.

5.3 Highest Deciduous Volumes

The highest deciduous CPA is produced when separate land bases are managed (#2+#16). Run #19 yields the highest PCP average for deciduous fibre, at 67,993M m^3/decade and the highest deciduous production over the PH, with 959,918M m^3. In #19, most of the pure conifer sites are harvested as soon as possible and are converted to pure deciduous. This integrated approach gives an increase in total volume of 8.0% over the PH. This results from a 3:1 substitution of deciduous for coniferous fibre; deciduous increases by 21% and conifer decreases by 7.3%.

Periodic constraints on hardwood production are identical for runs #18 and #19, but those on conifer are vastly different. #19 does not require any minimum level of conifer, whereas #18 requires 38,000M m^3/decade for the first 10 decades. Based on these constraints, it is expected that run #19 would have a lower conifer CPA and a greater deciduous CPA as compared to #18. However, the results are the exact opposite. Run #19 yields a higher conifer CPA of 50,335M m^3/decade (highest of any integrated run) and a lower deciduous CPA of 24,000 m^3/decade (lowest of all integrated runs). The deciduous CPA of #18 is roughly the same as run #19, however its conifer CPA is much lower (18.5%). However, in the PCP, #19 produces 34.8% more deciduous volume than does #18.

Runs #18 and #20 have the most stringent periodic constraint on conifer (minimum 38,000M m^3/decade for the first 10 decades) and vastly different deciduous constraints. In fact, run #20, which produces the second highest deciduous volume over the PH has no requirement on minimum level of deciduous. Its deciduous production is 30.7% greater over the CP and 25.6% higher over the PH as compared to #18, when a minimum deciduous volume/decade is required. The flow of deciduous volume in #20 however, is not uniform. In decades 7 and 8 the drop in harvest volume is severe, although all other decades during the CP have volumes similar to #17, #18, and #19. For #20, the majority of the land base, 52.3% (1.64 million hectares), is regenerated to mixedwood stands. 14.7% (462 thousand hectares) is regenerated to pure conifer stands, and 33.0% (1.04 million hectares) is regenerated to pure deciduous. Even without a constraint on the deciduous harvest, 33% of the landbase is regenerated as such.

The ranking of all Integrated runs from highest to lowest in terms of "Deciduous Volume of the PH" is:

	Deciduous Volume (m^3/decade)		
Run Number	CPA	PCP Average	PH
#19	24,000	67,993	959,918
#20	31,578	55,052	850,091
#17	24,146	54,239	795,740
#2+#16	31,602	48,337	793,576
#18	24,161	44,338	677,021

5.4 Highest Conifer Volumes

Run #19 gives the highest conifer CPA and the lowest total conifer production in the PCP and over the PH. Run #18 produces the highest conifer over the PH at the expense of deciduous production (as discussed in section 5.3).

The ranking of all Integrated runs from highest to lowest in terms of "Conifer Volume over the PH" is:

Conifer Volume (M m^3/decade)

Run Number	CPA	PCP Average	PH
#18	42,482	44,181	785,069
#17	42,961	40,976	749,471
#20	42,444	38,454	716,115
#2+#16	37,161	37,161	668,890
#19	50,335	26,505	620,063

5.5 Highest Total Volumes (Conifer + Deciduous)

Integrated run #19 yields the highest total volume in the CP, the PCP and over the PH when both products (conifer + deciduous) are added together.

Volume (m^3/decade) of #19

	CPA	PCP Average	PH
Conifer	50,335	26,505	620,063
Deciduous	24,000	67,993	959,918
Total Volume	74,335	94,498	1,579,981

At 74,335M m^3/decade, run #19 yields 8.1% more volume/decade in the CP and 10.5% greater volume/decade in the PCP as compared to managing the land bases separately (#2+#16). Total volume over the PH is comprised of 39% conifer and 61% deciduous. Originally, the integrated land

base was comprised of 51.4% pure deciduous timber types (1617.1M ha). In run #19, 39% of the land (1181.9M ha) is returned to pure deciduous production.

The ranking of all Integrated runs from highest to lowest in terms of "Total Volume over the PH" is:

Total Volume (Conifer + Deciduous) (m^3/decade)

Run Number	CPA	PCP Average	PH
#19	74,335	94,498	1,579,981
#20	74,022	93,506	1,566,206
#17	67,107	95,215	1,545,211
#2+#16	68,763	85,498	1,462,466
#18	66,643	88,519	1,462,090

5.6 Runs Superior to #2+#16

Two integrated land base runs exhibit superior volumes over the PH in all three areas (total conifer, total deciduous and total C+D volume) as compared to the summation of separate land bases.

Run Number	Total Conifer over PH	Total Deciduous over PH	Total C+D over PH
#20	716,115	850,091	1,566,206
#17	749,471	795,740	1,545,211
#2+#16	668,890	793,576	1,462,466

In run #20, the percent conifer (45.7%) contributing to total volume remains unchanged from that in managing separate land bases. In #17, this percentage is increased slightly, to 48.5% which gives 12% more conifer volume over the PH, while maintaining the same amount of deciduous (as compared to #2+#16). However, it may be desirable to keep the same

percentages as when managing separate land bases (#20) as this run yields 1.3% greater total volume over the PH than does run #17.

5.7 General Observations

The estimates for total fibre could be slightly higher than the results obtained for two reasons:

i) Timber stands may exist on the land base which did not meet merchantability standards for either land base. That is, stands which do not support 50 m^3/ha of conifer volume nor 50 m^3/ha of deciduous volume would not have been inventoried. Thus, some hectarage of land producing up to 98 m^3/ha (49 m^3/ha of conifer + 49 m^3/ha of deciduous) may have been omitted in the Phase 3 AFORISM data.

ii) Hardwood stands on the deciduous land base are typically not inventoried for softwood understories. The potential to have more mixedwood stands may exist.

6.0 CONCLUSIONS and RECOMMENDATIONS

6.1 Conclusions

With regard to the impact on allowable cut, when various options are used in reforesting conifer, mixedwood and deciduous stands (Objective 1), the study demonstrates:

- Regeneration of mixedwood stands to pure conifer plantations increases the conifer volume production by 5.9% over the planning horizon.
- This species conversion (mixedwood to conifer) increases the conifer LRSYA by 13.2%.
- Allowing mixedwood stands to revert to pure deciduous would decrease the conifer LRSYA by 36.5% and would decrease its volume production over the PH by 16.2%.
- The additional 4-year regeneration lag on good, conifer sites is insignificant in terms of total volume production over the PH. Removal of this extra lag would increase the conifer production by less than 1%.

With regard to the impact on allowable cut when intensive management is applied to mixedwood stands (Objective 2), the study concludes the following:

- Releasing mixedwood stands before age 60 increases the conifer volume production by 6.9% over the planning horizon.
- Continued regeneration-to and release-of mixedwood stands yields more conifer volume production over the PH than does

clearcut of mixedwood stands and conversion to pure conifer.

- Releasing mixedwood stands before age 60 and regenerating the mixedwood to pure conifer plantations can increase the conifer volume production by 13.6% over the planning horizon.
- Whether or not other conifers within the mixedwood stand respond to release treatments does not significantly impact conifer production over the PH.

With regard to utilizing/not utilizing the deciduous component of mixedwood stands (Objective 3), the conclusions are:

- Having to maintain a minimum flow of deciduous over the CP via managing species of regeneration, does not yield greater total volume (conifer + deciduous).
- If both release of mixedwood and management of species regeneration are employed, the total volume (conifer + deciduous) over the PH can be increased. This does not necessarily mean the greatest conifer or deciduous yields from the land base is achieved.
- Having to maintain a minimum flow of deciduous for the entire PH versus the first 10 decades, does not significantly decrease the conifer production; it does, however, significantly increase the deciduous production.

With regard to the effect on allowable cut when managing an integrated land base jointly for both hardwood and softwood production versus two separate land bases (Objective 4), the study concludes:

- An integrated land base can yield superior volumes in terms of greater conifer, greater deciduous and greater total production as compared to combining the volumes attainable from separate land bases.
- Through different flow constraints, the integrated land base can be managed for greater deciduous:coniferous production or vice versa.
- If minimum flow constraints are placed on the deciduous and coniferous components within an integrated land base, some portion of pure deciduous and pure coniferous stands will be maintained.
- the linear program reforests the majority of the land base to the highly productive mixedwood forest.

6.2 Recommendations

Policies arise from (a) beliefs, emotions and/or behaviors and/or (b) data. The best policy decisions result from integrating (a) with (b). The current policy for classifying forested stands into their respective land base is based: on past beliefs -- conifer is more valuable than deciduous; on past behaviors -- forest industry in Alberta has used little aspen; and on past data -- softwood has been the preferred species. With the recent changes in beliefs with regard to the value of softwood and hardwood, and in behaviors with regard to species utilization, the current government policy for defining the coniferous and deciduous land base needs to be challenged. This study uses scientific tools to introduce relevant data that could be used in modifying the current policy, or in creating a new one.

This study suggests that an integrated land base may be necessary, as more deciduous, more coniferous and more total volume can be attained from the same land area through different forest management practices. The current government policy should be reconsidered especially for those forests situated in the Mixedwood Section of the Boreal Forest Region.

Further studies are needed to answer questions with regard to how an integrated land base should be managed. Would the definition of a merchantable conifer stand change from the present "conifer bias" to equalize the value of the deciduous

resource? How would mixedwood stands be defined? Would they continue to be inventoried under the categories of C/D or D/C? How should the land base be defined? Would it be one integrated land base or would a third, mixedwood land base, evolve? How would forest land tenure be assigned to a forestry company if it did not utilize both softwood and hardwood fibre? Would the company own the rights to all timber, would a third-party agency optimize trading of species between companies, would the government direct wood fibre for the province, or would tenure on the Forest Management Areas be shared? Sharing tenure leads to many more complex questions regarding economic factors: what is the comparative value of conifer and deciduous and from whose viewpoint? Who pays for the production costs associated with releasing an understorey, or the road systems? If species conversion based on site growth characteristics is to be optimized, how would the companies deal with their continually changing land base, and who would own the responsibility for meeting the reforestation regulations?

In this study, optimization of allowable cut is the only factor evaluated. If this is the sole use of the forest, an integrated land base appears superior. Before a conclusion on superiority is made, further studies are needed to explore the logistics of investment analysis and of managing an integrated land base for other land uses such as wildlife, recreation and watershed.

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APPENDIX:
YIELD TABLES

Appendix I Table 1: Standing Timber Volumes
for Conifer Timber Types
in Existing Forest
[Timber Classes A-C]

Timber Class: A Species: Conifer Site Class: Good Yield Tables #1,2		Timber Class: B Species: Conifer Site Class: Medium Yield Tables #5,6		Timber Class: C Species: Conifer Site Class: Fair Yield Tables #3,4	
Age (decades)	Standing Timber Volume (m3/ha)	Age (decades)	Standing Timber Volume (m3/ha)	Age (decades)	Standing Timber Volume (m3/ha)
1	0.00	1	0.00	1	0.00
2	0.00	2	0.00	2	0.00
3	24.43	3	4.40	3	0.00
4	48.85	4	8.81	4	0.00
5	85.94	5	39.16	5	0.00
6	123.00	6	69.50	6	0.00
7	152.90	7	103.00	7	18.22
8	182.70	8	136.40	8	36.44
9	203.10	9	163.20	9	59.86
10	223.50	10	189.90	10	83.27
11	240.20	11	213.50	11	107.50
12	256.90	12	237.10	12	131.70
13	267.40	13	254.80	13	151.60
14	277.80	14	272.40	14	171.50
15	285.80	15	286.50	15	189.70
16	293.70	16	300.50	16	207.90
17	299.10	17	309.60	17	220.10
18	304.30	18	318.80	18	232.20

Appendix I. Table 2: Standing Coniferous Timber Volumes in Mixedwood Timber Types of Existing Forest [Timber Classes D - F]

Timber Class: D Species: Mixedwood Site Class: Good Yield Tables #7-19		Timber Class: E Species: Mixedwood Site Class: Medium Yield Tables #20-32		Timber Class: F Species: Mixedwood Site Class: Fair Yield Table #33	
Age (decades)	Coniferous: Standing Timber Volume (m3/ha)	Age (decades)	Coniferous: Standing Timber Volume (m3/ha)	Age (decades)	Coniferous: Standing Timber Volume (m3/ha)
1	0.00	1	0.00	1	0.00
2	0.00	2	0.00	2	0.00
3	5.75	3	0.00	3	0.00
4	11.49	4	0.00	4	0.00
5	51.66	5	6.61	5	0.00
6	91.45	6	13.22	6	0.00
7	126.90	7	42.70	7	2.31
8	162.40	8	72.18	8	4.62
9	188.00	9	97.51	9	23.81
10	213.60	10	122.90	10	43.00
11	232.20	11	142.80	11	62.92
12	250.70	12	162.70	12	82.83
13	264.50	13	178.50	13	99.78
14	278.30	14	194.20	14	116.70
15	288.70	15	206.70	15	131.10
16	299.10	16	219.10	16	145.40
17	305.40	17	226.70	17	0.00 *
18	311.70	18	234.60	18	0.00 *

* No conifer volumes inventoried on the AFORISM data in the Slave Lake forest for these age classes/species/site combinations.

Appendix I Table 3: Standing Deciduous Timber Volumes in Mixedwood Timber Types on Existing Forest [Timber Classes D - F]

Timber Class: D Species: Mixedwood Site Class: Good Yield Tables #7-19		Timber Class: E Species: Mixedwood Site Class: Medium Yield Tables #20-32		Timber Class: F Species: Mixedwood Site Class: Fair Yield Table #33	
Age (decades)	Deciduous Standing Timber Volume (m3/ha)	Age (decades)	Deciduous Standing Timber Volume (m3/ha)	Age (decades)	Deciduous Standing Timber Volume (m3/ha)
1	0.00	1	0.00	1	0.00
2	0.00	2	0.00	2	0.00
3	0.00	3	0.00	3	0.00
4	11.61	4	0.00	4	0.00
5	34.29	5	5.99	5	2.32
6	54.10	6	24.67	6	4.64
7	69.13	7	42.54	7	17.38
8	69.13	8	50.01	8	30.11
9	69.13	9	67.12	9	42.90
10	0.00	10	0.00	10	55.69
11	0.00	11	0.00	11	66.23
12	0.00	12	0.00	12	0.00
13	0.00	13	0.00	13	0.00
14	0.00	14	0.00	14	0.00
15	0.00	15	0.00	15	0.00
16	0.00	16	0.00	16	0.00
17	0.00	17	0.00	17	0.00
18	0.00	18	0.00	18	0.00

Note:
Imposed the 0 m3/hectare at age 100 as per literature on aspen decay; forces harvest at these ages on G and M. Fair sites are harvested at administratively set rotation age for mixedwood, thus still show vol/ha.

Appendix I Table 4: Standing Timber Volumes for Deciduous Timber Types in the Existing Forest [Timber Classes G - I]

Timber Class: G Species: Deciduous Site Class: Good Yield Table #34,35		Timber Class: H Species: Deciduous Site Class: Medium Yield Table #36,37		Timber Class: I Species: Deciduous Site Class: Fair Yield Table #38	
Age (decades)	Standing Timber Volume (m3/ha)	Age (decades)	Standing Timber Volume (m3/ha)	Age (decades)	Standing Timber Volume (m3/ha)
1	0.00	1	0.00	1	0.00
2	0.00	2	0.00	2	0.00
3	4.96	3	0.00	3	0.00
4	49.92	4	6.48	4	0.00
5	83.69	5	55.23	5	0.00
6	109.60	6	93.42	6	8.82
7	130.10	7	124.40	7	40.25
8	118.20	8	123.90	8	65.17
9	126.60	9	137.30	9	73.75
10	134.90	10	150.70	10	88.09
11	0.00	11	0.00	11	98.56
12	0.00	12	0.00	12	0.00
13	0.00	13	0.00	13	0.00
14	0.00	14	0.00	14	0.00
15	0.00	15	0.00	15	0.00
16	0.00	16	0.00	16	0.00
17	0.00	17	0.00	17	0.00
18	0.00	18	0.00	18	0.00

Decay assumptions as per Appendix I, Table 3.

Appendix I Table 5: Standing Timber Yield Table Values for Mixedwood stands under Management Practice of Release of 50-60 year-old stands of Existing Forest

Timber Class:	D		Timber Class:	D		Timber Class:	D	
Species:	Mixedwood		Species:	Mixedwood		Species:	Mixedwood	
Site Class:	Good		Site Class:	Good		Site Class:	Good	
Mgmt Practice:	Release of 50-60 yr MW		Mgmt Practice:	Release of 50-60 yr MW		Mgmt Practice:	Release of 50-60 yr MW:	
Response:	white spruce has addtional 260 m3/ha 40 years after release		Response:	Response of other conifers 1.25X vol.		Response:	Response of other conifers 1.5X vol.	
Regeneration Option:	Mixedwood		Regeneration Option:	Mixedwood		Regeneration Option:	Mixedwood	
Regeneration Lag:	4 years		Regeneration Lag:	4 years		Regeneration Lag:	4 years	
Age (decades)	Standing Timber Volume (m3/ha)	Second-growth Forest Volume (m3/ha)	Age (decades)	Standing Timber Volume (m3/ha)	Second-growth Forest Volume (m3/ha)	Age (decades)	Standing Timber Volume (m3/ha)	Second-growth Forest Volume (m3/ha)
1	0.00		1	0.00		1	0.00	
2	0.00		2	0.00		2	0.00	
3	5.75		3	5.75		3	5.75	
4	11.49		4	11.49		4	11.49	
5	51.46		5	51.46		5	51.46	
6	91.45		6	91.45		6	91.45	
7	126.90		7	126.90		7	126.90	
8	210.50	193.00	8	210.50	193.00	8	210.50	193.00
9	279.70		9	279.70		9	279.70	
10	358.40		10	368.30		10	378.20	
11	377.80		11	387.70		11	397.60	
12	395.60		12	405.50		12	415.40	
13	409.30		13	419.20		13	429.00	
14	423.10		14	433.00		14	442.80	
15	433.60		15	443.50		15	453.30	
16	444.00		16	453.90		16	463.70	
17	450.30		17	460.20		17	470.00	
18	456.60		18	466.50		18	476.30	

Notes: 1. For runs where mixedwood stands are regenerated to pure conifer, the standing timber volumes/hectare remain the same as above; the regenerated volume of the second growth forest changes from 193.0 m3/ha in decade 8 to 221.0 m3/ha in decade 7 as per Appendix I, Table 7.

2. Mixedwood stands growing on Medium site classes show similar growth response as above, but yields are applied to volume/ha on medium sites; addt'l Sw growth of 189 m3/ha.

Appendix I Table 6: Standing Timber Yield Table Values for Mixedwood stands when Management Practice of Release is applied to 40-year-old stands of Existing forest

Timber Class:	D		Timber Class:	D		Timber Class:	D	
Species:	Mixedwood		Species:	Mixedwood		Species:	Mixedwood	
Site Class:	Good		Site Class:	Good		Site Class:	Good	
Management Practice:	Release @ 40 yr		Management Practice:	Release @ 40 yr		Management Practice:	Release @ 40 yr	
Response:	other conifers = zero		Response:	other conifers @ 1.25X		Response:	other conifers @ 1.5X	
Regeneration Option:	Mixedwood		Regeneration Option:	Mixedwood		Regeneration Option:	Mixedwood	
Regeneration Lag:	4 years		Regeneration Lag:	4 years		Regeneration Lag:	4 years	
Age (decades)	Standing Timber Volume (m3/ha)	Second-growth Forest Volume (m3/ha)	Age (decades)	Standing Timber Volume (m3/ha)	Second-growth Forest Volume (m3/ha)	Age (decades)	Standing Timber Volume (m3/ha)	Second-growth Forest Volume (m3/ha)
1	0.00		1	0.00		1	0.00	
2	0.00		2	0.00		2	0.00	
3	5.75		3	5.75		3	5.75	
4	11.49		4	11.49		4	11.49	
5	61.15		5	61.15		5	61.15	
6	148.90		6	148.90		6	148.90	
7	222.30		7	222.30		7	222.30	
8	305.00	193.00	8	314.80	193.00	8	324.70	193.00
9	330.50		9	340.40		9	350.20	
10	356.10		10	365.00		10	375.80	
11	374.70		11	384.60		11	394.40	
12	393.30		12	403.10		12	413.00	
13	407.00		13	416.90		13	426.70	
14	409.50		14	419.40		14	429.20	
15	417.10		15	427.00		15	436.80	
16	441.70		16	451.60		16	461.40	
17	448.00		17	457.90		17	467.70	
18	453.90		18	463.80		18	473.60	

Notes: 1. For runs where mixedwood stands are regenerated to pure conifer, the standing timber volumes/hectare remain the same as above; the regenerated volume of the second growth forest changes from 193.0 m3/ha in decade 8 to 221.0 m3/ha in decade 7 as per Appendix I, Table 7.

2. Growth response for mixedwood stands on Medium site classes show similar growth response after release, but are applied to yields/ha as per medium site classes.

Appendix I: Table 7 Volumes at Rotation of Second Growth Forests

Timber Class	Timber Type	Site Class	Regenerated To	Regen Lag (years)	Rotation Age (decade)	Regen'd Conifer Volume at Rotation (m3/ha)	Regen'd Decid. Volume at Rotation (m3/ha)	Regen'd Total Volume at Rotation (m3/ha)
A	Conifer	Good	Pure Conifer	4	7	221.0	0.0	221.0
A	Conifer	Good	Pure Conifer	8	7	209.0	0.0	209.0
A	Conifer	Good	Mixedwood	4	8	193.0	141.0	334.0
B	Conifer	Medium	Pure Conifer	4	8	179.0	0.0	179.0
B	Conifer	Medium	Mixedwood	4	8	147.0	108.0	255.0
C	Conifer	Fair	Pure Conifer	4	10	127.0	0.0	127.0
C	Conifer	Fair	Mixedwood	4	11	121.0	58.6	179.6
D	Mixedwood	Good	Pure Conifer	4	7	221.0	0.0	221.0
D	Mixedwood	Good	Mixedwood	4	8	193.0	141.0	334.0
D	Mixedwood	Good	Deciduous	0	7	0.0	280.0	280.0
E	Mixedwood	Medium	Pure Conifer	4	8	179.0	0.0	179.0
E	Mixedwood	Medium	Mixedwood	4	9	147.0	108.0	255.0
E	Mixedwood	Medium	Deciduous	0	7	0.0	228.0	228.0
F	Mixedwood	Fair	Mixedwood	4	11	121.0	58.6	179.6
G	Deciduous	Good	Mixedwood	4	8	193.0	141.0	334.0
G	Deciduous	Good	Deciduous	0	7	0.0	280.0	280.0
H	Deciduous	Medium	Mixedwood	4	9	147.0	108.0	255.0
H	Deciduous	Medium	Deciduous	0	7	0.0	228.0	228.0
I	Deciduous	Fair	Mixedwood	4	11	121.0	58.6	179.6

Note: Mixedwood stands on Good Sites regenerating to Pure Conifer have regen lag of 4 years (versus 8) and yield of 221 m3/ha (versus 209) as intensive forest management is applied to achieve species conversion.

Appendix I Table 8: Yield Table Numbers Corresponding to Site, Species, and Regeneration Method and Regeneration Method

Yield Table Number

Initial Forest & Treatment	Regenerated to: Conifer	Mixedwood	Deciduous
Conifer	G #1	G #2	N/A **
	M #3	M #4	N/A **
	F #5	F #6	N/A **
Clearcut MW Stands	G #7	G #8	G #9
	M #20	M #21	M #22
	F N/A	F #33	F N/A **
Release of 60 yr. MW + Herbicide	G #10	G #11	N/A ***
	M #23	M #24	N/A ***
Release of 40 yr. MW + Herbicide	G #15	G #16	N/A ***
	M #28	M #29	N/A ***
Release of 60 yr. MW NO Herbicide	G #12	G #13	G #14
	M #25	M #26	M #27
Release of 40 yr. MW NO Herbicide	G #17	G #18	G #19
	M #30	M #31	M #32
Deciduous	N/A *	G #35	G #34
	N/A *	M #37	M #36
	N/A *	F #38	F N/A **

Notes: 1. These yield tables incorporate Standing Timber Volumes from Appendix I, Tables 1-6 with Regen Volumes from Table 7.

2. * Deciduous stands on good sites would not be converted to conifer

** Fair site classes are not regenerated to deciduous.

*** With herbicide being applied after entry cut, there should not be any parent trees left that could give rise to suckers.

3. G = Good Site Class
M = Medium Site Class
F = Fair Site Class